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RAKE Receiver for Time Division Synchronous CDMA Mobile Terminal

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Abstract

For the sake of the potential ability of overcoming interference in TD-SCDMA(time division-synchronous code division multiple access) systems, pilot signal is adopted, but the presented TD-SCDMA protocol has not considered the Rake technique for their mobile terminals. This paper developed a RAKE receiver algorithm and an implementation circuit, which make use of the pilot signal in the burst structure of the TD-SCDMA base station to estimate main channel parameter(channel delays) in the downlink of TD-SCDMA wireless network. The algorithm can reduce multipath interference for the mobile units in multiusers' case. Theoretic performance analysis presented in the paper and computer simulations show that there is a range of BER for Rake receiver and confirm that the proposed RAKE receiver algorithm achieved a better performance under multipath fading propagation and multiusers conditions.

Key words : TD-SCDMA RAKE Receiver Schemes, Channel Parameters Estimation, Wireless Communication Systems.

Ⅰ. Introduction

TD-SCDMA standard seems to be a promising approach for implementing cellular communication services[1],[2]. Though D-SCDMA has absorbed many new techniques recent proposed, it did not consider Pre-Rake and the Rake techniques for its base stations and mobile stations[3]~[5] for its implementation of future wireless services. One of the greatest impairments to mobile radio is the fading nature of the channel[3]~[10]. When transmitting over a frequency-selective fading channel, the interference rejection property of direct-sequence (DS) dictates that any multipath component which is at least one chip out of synchronization with the despreading pseudonoise(PN) sequence will be seen as approximately equivalent to white noise, thus decreasing the multipath component's ability to degrade system performance. The ability of DS to resolve individual components from the overall multipath signal allows for the reception of many components if a RAKE receiver is used and improved performance through diversity combining[3]~[10].

Though the method of channel estimation for mobile terminals to employ the sequence of pilot symbols has been involved[6]~[10], the implementation complexity of Rake receivers and the burst structure of TD-SCDMA have not been considered[5]. To solve the above problems and improve the communication quality of the downlinks of TD-SCDMA, this paper provides an algorithm and a Rake circuit structure, which are of channel parameter estimation in a RAKE receiver based on TD-SCDMA burst structure. Theory analysis and numerical simulation results are used to demonstrate the performance of the proposed RAKE receiver in terms of bit error probability under multipath fading propagation conditions, even compared with the SIR Rake receivers[11],[12].

Ⅱ. The Burst Structure of TD-SCDMA

All physical channels TD-SCDMA systems take four-layer structure of superframes, radio frames, subframes and time slots/codes[2]. Depending on the resource allocation, the configuration of subframes or time slots becomes different. All physical channels need guard symbols in every time slot. The time slots/codes are used in the sense of a TDMA component to separate different user signals in the time and the code domain. The physical channel signal format is presented in Fig. 1. The basic physical channel is defined as the association of one code, one time slot and one frequency. The radio frame has a duration of 10 ms and is subdivided into 2 subframes of 5 ms each, and each subframe shown in Fig. 2 is then subdivided into 7 main time slots(TS) of 675 μs duration each and 3 special time slots: DwPTS(Downlink Pilot) shown in Fig. 3, G(Guard period) and UpPTS(Uplink Pilot). The physical contents of the time slots are the bursts of corresponding

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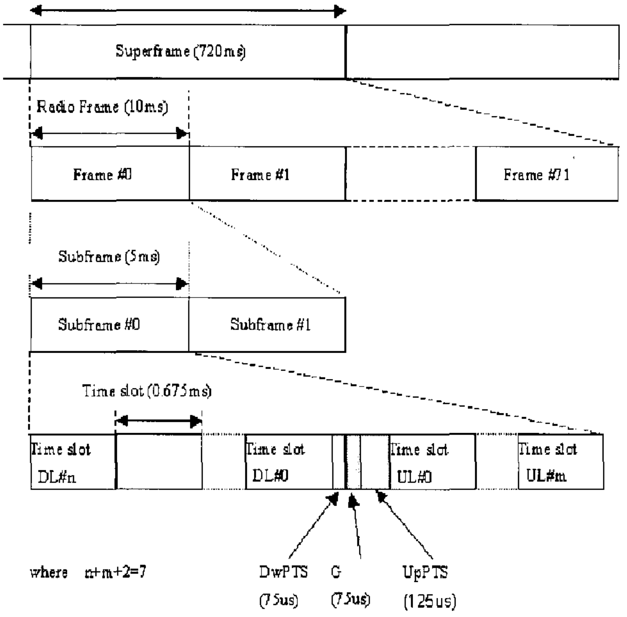

Fig. 1. Physical channel structure of TD-SCDMA.

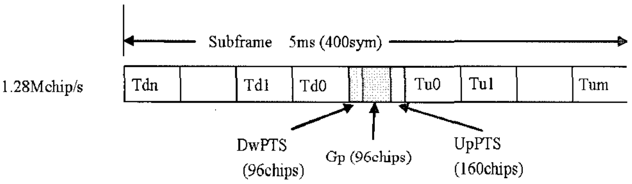

Fig. 2. Sub-frame structure of TD-SCDMA.

length as described in Fig. 4.

The DwPTS(SYNC-Synchronization Chips) in each subframe is designed for both downlink pilot and SCH. The base station would transmit it omnidirectionally or sectorially at the full power level. This DwPTS time slot is usually composed of 64 chips of SYNC and 32 chips of guard period as shown in Fig. 3. The contents in the SYNC are a set of gold code. The gold code set is designed to distinguish nearby cells for the purpose of easier cell measurement. The set of code could be repeated in the cellular network. The proposed mobile Rake can resort to DwPTS to determine the fingers' positions.

Each time slot of length 675 μs consists of two data symbol fields, a midamble of 144 chips and a guard period of 16 chips. The data fields of the burst type are 704 chips long. The training sequences, i.e. midamble, of different users active in the same time slot are time-shifted versions of one single periodic basic code. Different cells use different periodic basic codes, i.e. different midamble sets. In this way joint channel estimation for the channel impulse responses of all active users within one time slot can be done by one single cyclic correlation. Thus, the different user specific channel impulse response estimations can be also obtained sequentially in time at proposed mobile Rake. The midamble transmitting power of TD-SCDMA base stations is the same as the data symbols in the same burst.

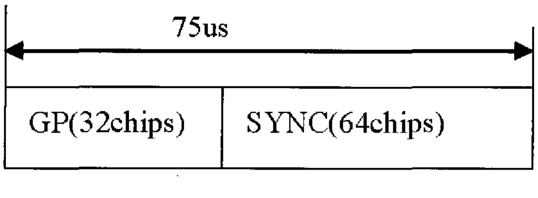

Fig. 3. Burst structure of DwPTS.

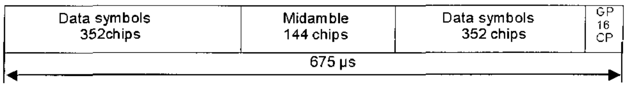

Fig. 4. Burst structure of the time slot(GP denotes the guard period and CP the chip period).

Now, we can see that TD-SCDMA mobile Rakes can have two ways to get channel information: DwPTS chips and midamble chips, and can use either of them as training sequences to get fingers. In the paper, we mainly study the rake tracing the midamble chips, and in the following section, we define the data symbol fields as data slot, and midamble field as pilot slot, see Eq. (2) in the following section.

Ⅲ. Digital Detection Algorithm

For the sake of simplicity, the TD-SCDMA system under consideration is assumed as formed by a single isolated circular cell of radius R with a centrally located base-station. In particular, the focus here is on downlink communications. It is assumed that the base station communicates with the K spatially dispersed mobile users by a TD-SCDMA scheme. All the K transmitted signals from the TD-SCDMA base-station have experienced identical fading when received by a particular mobile user. These users are assumed to be uniformly distributed throughout the cell area.

A frequency-selective slowly fading transmission channel has been assumed as the Ref. [3]~[10].

$$h_k(t)=\sum_{l=1}^{L}\alpha_{k,l}e^{j\theta_{k,l}}\delta(t-\tau_{k,l}) \tag{1}$$

where $\alpha_{k,l}$ is attenuation introduced by the l-path; $\theta_{k,l}$: phase shift introduced by the l-path, defined in the [0, 2π] interval; $\tau_{k,l}$: time delay introduced by the l-path for $1 < \le l \le L$, with L denoting the number of resolvable paths. Different from Ref. [6], our TD-SCDMA mobile Rake receivers need not to estimate all the parameters

$\{\alpha_{k,l}, \theta_{k,l}, \tau_{k,l}\}$, only need to $\tau_{k,l}$ estimate by means of a pilot signal at burst dada frame, which is broadcasted by TD-SCDMA base station to all the mobile users in the cell, since in TD-SCDMA burst structure pilot sequence and data symbol sequence are located in different time slots, which is shown in Fig. 4. We need not cancel the interference of pilot sequence to data symbol sequence like [6], so the complexity problem of the parameters $\{\alpha_{k,l}, \theta_{k,l}, \tau_{k,l}\}$ can be solved.

We assumed that the received signal $\tau_k(t)$ for the kth mobile user is given by the sum of the output of a linear system having a randomly time-varying impulse response, and an AWGN term $n_k(t)$ with zero mean and two-sided power spectral density $N_0/2$. The multipath effects are represented as a sequence of replicas of the transmitted signal, each one characterized by a particular delay, phase and attenuation. We have assumed parameter L(i.e., the number of resolvable paths in our channel model) and considered negligible the intersymbol interference introduced by the downlink channel, i.e., $\tau_{k,i} < 0.2\,T_b$ for $1 \le i \le L$, with $T_b = NT_c$ the bit duration. T_c is the spreading chip duration.

QPSK modulation scheme is used in the transmission of TD-SCDMA communication system. The baseband representation of the in-phase and quadrature components of the transmitted signal from the base station to the kth mobile user in its cell is

$$s_k(t) = \begin{cases} b_k(t)\,c_{k,I}(t) + jd_k(t)\,c_{k,Q}(t), & \text{data slot} \\ c_E(t), & \text{pilot slot} \end{cases} \tag{2}$$

where $b_k(t) = \sum_{n=0}^{\infty} b_k(n)\,q(t-nT_b)$, $d_k(t) = \sum_{n=0}^{\infty} d_k(n)\,q(t-nT_b)$, $q(t) = \begin{cases} 1 & 0 \le t < T_b \\ 0 & otherwise \end{cases}$, $\{b_k(n)\}$ is in-phase data sequence of kth mobile user, with $b_k(n)$ equal to ±1 with equal probability; $\{d_k(n)\}$ is quadrature data sequence, with $d_k(n)$ equal to ±1 with equal probability.

The following pseudonoise(PN) code sequences in Eq. (2) have following forms

$$c_{k,I} = \frac{\sqrt{P}}{2} \sum_{n=0}^{N-1} c_{k,I}(n)\,p(t-nT_c) \tag{3a}$$

$$c_{k,Q} = \frac{\sqrt{P}}{2} \sum_{n=0}^{N-1} c_{k,Q}(n)\,p(t-nT_c) \tag{3b}$$

where $\{c_{k,I}(n)\}$ - PN sequence associated with the in-phase component, with $c_{k,I}(n)$ equal to ±1(binary chip); $\{c_{k,Q}(n)\}$ - PN sequence associated with the quadrature component, with $c_{k,Q}(n)$ equal to ±1(binary chip); M-th number of chips in the PN sequence(or chips/bit); P denotes the power of the PN sequence with respect to $c_{k,I}(n)$, and

$$p(t) = \begin{cases} 1 & 0 \le t < T_c \\ 0 & otherwise \end{cases} \tag{4}$$

Additionally, a PN signal(pilot signal) from a TD-SCDMA base station is added to the downlink transmitted signal in order to perform the channel parameter estimation.

The pilot signal in (2) is defined as

$$c_E(t) = \frac{\sqrt{P}}{2} \sum_{n=0}^{N-1} c_E(n)\,p(t-nT_c) \tag{5}$$

where $c_E(n)(=\pm 1)$ are the binary chips forming the PN sequence, pilot signal power P is equal to that of PN sequence.

From Eq. (1) and Eq. (2), if K users are active in a TD-SCDMA cell, it is straightforward to see that the received signal(baseband) for the kth mobile is

$$r_k(t) = \begin{cases} \sum_{i=1}^{L_1} \alpha_{k,i} e^{j\theta_{k,i}} \sum_{n=1}^{K} [\,b_m(t)\,c_{m,I}(t-\tau_{k,i}) \\ \qquad + j[\,d_m(t)\,c_{m,Q}(t-\tau_{k,i})], & \text{data slot} \\ \sum_{i=1}^{L} \alpha_{k,i} c_E(t-\tau_{k,i}) e^{j\theta_{k,i}} + n_k(t), & \text{pilot slot} \end{cases} \tag{6}$$

where L_1 is the number of fingers of Rake, and $L_1 < L$. The digital detection considered here permits to track the channel variations by evaluating the sliding correlation of the received signal $r_k(t)$ with a locally generated pilot sequence $c_E(t)$ as

$$c_k(t) = \frac{1}{T_b} \int_{nT_b}^{(n+1)T_b} r_k(t)\,c_E(t-\tau)\,dt \tag{7}$$

for $\forall \tau \in [0, lT_c]$ and $l = 0, \ldots, N-1$. By substituting (6) into (7) and taking into account the assumption of slow fading(i.e., by considering constant the channel parameters over at least two bit intervals) we have

$$c_k(t) = c_{k,EE}(t) + c_{k,En}(t). \tag{8}$$

We have the contribution of the auto-correlation between $c_E(t)$ and every received replica of $c_E(t)$ in the fingers $L_1 < L$ replicas, where L_1 is the number of fingers of the Rake. When $t = \tau_{k,i}$ as following

$$c_{k,EE} = \sum_{i=l}^{L_1} [\,\alpha_{k,i} \frac{\sqrt{P}}{2}\, e^{j\theta_{m,i}} z(t-\tau_{k,i})] \tag{9}$$

where $z(x)$ is equal to 1 if $x = 0$, else to zero.

When $t \neq \tau_i$, $c_{k,EE}(t)$ becomes

$$c_{k,EE} = \frac{1-\xi(t-\tau_{k,i})}{T_b} \int_{nT_b}^{(n+1)T_b} \sum_{i=l}^{L_1} \alpha_{k,i} c_E(\sigma-\tau_{k,i})\,c_E(\sigma-t)\,d\sigma \tag{10}$$

The contribution of the cross-correlation between $c_E(t)$ and $n_K(t)$ is as following

$$c_{k,En}(t) = \frac{1}{T_b} \int_{nT_b}^{(n+1)T_b} \sum_{i=l}^{L_1} n_k(\sigma)\,c_E(\sigma-t)\,d\sigma \tag{11}$$

Then, the sliding correlation at the pilot slot, evaluated on the time interval $[nT_b,(n+1)T_b]$, gives

$$c_k(t) \cong \sum_{i=l}^{L_1} a_{k,i} \frac{\sqrt{P}}{2} e^{j\theta_{k,k}} z(t-\tau_{k,i}) \tag{12}$$

Furthermore, we assume that $|\tau_{k,i}-\tau_{k,j}| > T_c, \forall i \neq j$ where- $\tau_{k,i}$ and $\tau_{k,j}$ are the time delays introduced by the i-path and the j-path, respectively.

In order to obtain the channel parameters estimation, the mobile Rake evaluates the squared module of $c_k(t)$ defined as

$$\begin{aligned} D_k(t) &= Re^2\{c_k(t)\} + Im^2\{c_k(t)\} \\ &\cong \sum_{k=1}^{K} \sum_{i=1}^{L_1} a_{k,i}^2 \frac{P}{2} z(t-\tau_{k,i}). \end{aligned} \tag{13}$$

The delays associated with the L paths are found by searching for the $t=\tau_{k,j}$, with j=1, 2, $\cdots$, L_1, for which $D_k(\tau_{k,j})$ assumes maximum values in the interval $[nT_b, (n+1)T_b]$.

Hence, by Eq. (11) the Rake gets the fingers' positions

$$\tau_{k,j} = lT_c, \quad j=1,2,\cdots,L_1, \quad l \in \{1,\cdots,N-1\}. \tag{14}$$

Now, we can see that different from Ref. [6], our TD-SCDMA mobile Rake receivers need not to estimate all the parameters $\{a_{k,l}, \theta_{k,l}, \tau_{k,l}\}$, only need to $\tau_{k,l}$ estimate by Eq. (11) searching $D_k(\tau_{k,j})$ with j=1, 2, $\cdots$, L_1, at the pilot slot. Thus, the proposed Rake algorithm can reduce the implementation complexity.

Obtained the fingers positions $\tau_{k,l}$, j=1, 2, $\cdots$, L_1, at data slot each RAKE arm directly dispreading received transmitted symbols,

$$c_{k,I}(\tau_{k,j}) = \frac{1}{T_b} \int_{\tau_j}^{\tau_j+T_b} r_k(t) c_{k,I}(t-\tau_{k,j}) dt \tag{15a}$$

$$c_{k,Q}(\tau_{k,j}) = \frac{1}{T_b} \int_{\tau_j}^{\tau_j+T_b} r_k(t) c_{k,Q}(t-\tau_{k,j}) dt \tag{15b}$$

By assuming the noise term to be negligible, we have the contribution of the cross-correlation terms

$$c_{k,I}(\tau_{k,j}) = b_k(n) a_{k,j} e^{j\theta_{k,j}} \tag{16a}$$

$$c_{k,Q}(\tau_{k,j}) = j d_k(n) a_{k,j} e^{j\theta_{k,j}} \tag{16b}$$

Equations (16a) and (16b) are related to the information components associated with the jth path affected by a phase-shift $\theta_{k,j}$ introduced by the communication channel.

The in-phase $I_{k,j}(n)$ and quadrature $Q_{k,j}(n)$ data decision variables related to the j th path and n th bit are obtained as:

$$I_{k,j}(n) = c_{k,I}(\tau_{k,j}) c_{k,I}^*(\tau_{k,j}) \tag{17a}$$

$$Q_{k,j}(n) = -j c_{k,Q}(\tau_{k,j}) c_{k,Q}^*(\tau_{k,j}) \tag{17b}$$

The received data from the in-phase and quadrature overall decision variables are formed(the decision threshold value has been set at zero),

$$b_k(n) = \begin{cases} 1, & \text{if } \sum_{j=1}^{L_1} I_{k,j}(n) > 0 \\ 0, & else \end{cases} \tag{18a}$$

and

$$d_k(n) = \begin{cases} 1, & \text{if } \sum_{j=1}^{L_1} Q_{k,j}(n) > 0 \\ 0, & else \end{cases} \tag{18b}$$

From above results, we can give our brief Rake receiver to be shown in Fig. 5. In the figure, the switch is controlled by pilot sequence, the finger search block completes the searching of $D_k(\tau_{k,j})$ in Eq. (13), the obtained fingers positions $\tau_{k,l}$ to be provided to symbols spreading block for fingers assigning. Completed the fingers assigning, the input signals are switched to the symbols spreading block, which spreads the signals according to Eqs. (15)~(17). The output of the block is sent to diversity combining and decision block to produce final results according to Eq. (18).

Remark: Figure

1. Limited by implementation condition, a practical mobile Rake receiver can have fewer fingers, in fact, only one time-switching matched filter to complete all the work in Fig. 5 in different epoch of the pilot slot and data slot. In pilot slot, the matched filter catches the different possible fingers at the limited pilot slot, each search will occupy some fraction of the slot. In data slot, the case is similar. The matched filter needs to collect the time diversity information at different fingers at the limited data slot, each collection will also occu-

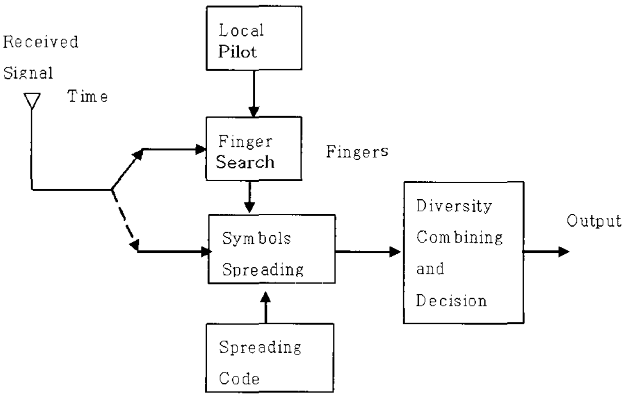

Fig. 5. The proposed Rake receiver.

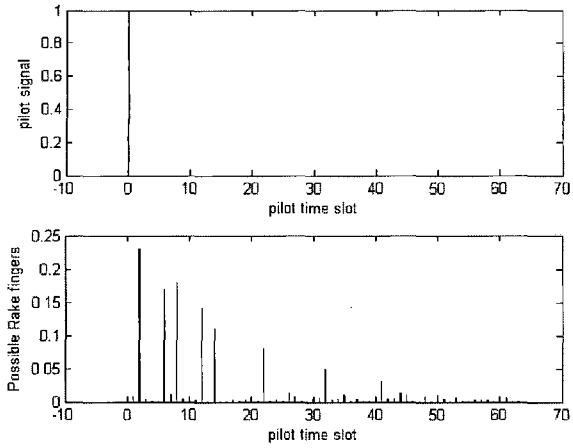

Fig. 6. The pilot sequence in one and the fingers of the mobile Rake.

py some fraction of the slot.

2. Suppose that the mobile Rake receiver has L fingers, the pilot length is the midamble of 144 chips in Fig. 2, the finger delay to $\tau_{k,i}<0.2\ T_b$ for $1\leq i\leq L_1$, with $T_b=NT_c$, and also consider the research epoch for one finger due to Eq. (14), then we can obtain the maxim number of fingers in one T_b slot to be 0.2 N. However, it is not necessary, since the received time diversity signal energy is focus on the main fingers.
3. For $T_b=NT_c$, and N=64, the fingers' delay $\tau_{k,i}<0.2\ T_b$, the pilot sequence in one symbol bit can be designed into [1, 0, ⋯,0] of length 64 T_c, shown in Fig. 6, then the positions of the figures of the mobile Rake can be obtained from the channel impulse response, also shown in Fig. 6. The Rake fingers are selected the main channel impulses only, considering the implementation complexity. The Rake completes the search for fingers in one T_b.

Ⅳ. Performance of Rake Receivers with Imperfect Channel Estimation

Now we assume that there are K users in the system, and user k is the desired one, then we get the received signal $r_k(t)$ as follows

$$r_k(t)=Re\sum_{m=1}^{k}\sum_{i=0}^{L-1}\alpha_{k,i}s_m(t-\tau_{k,i})e^{i\theta_{k,i}}+n_k(t) \tag{19}$$

where $n_k(t)$ is the zero-mean additive white Gaussian noise(AWGN) with two-sided power spectral density $N_0/2$, and $s_m(t)$ is given by (2). The TD-SCDMA mobile units use maximal ratio combining to collect the power from different path by above algorithms. We can get the in-phase and quadrature data outputs of the kth rake receiver as

$$\begin{aligned} r_{k,I}(t) &= \sum_{i=0}^{L_1-1}\alpha_{k,i}\int_{nT_b}^{(n+1)T_b} r_k(t)c_{k,I}(t-\tau_{k,i})\cos(\theta_{k,i})dt \\ &= D_{k,I}+S_{k,I}+A_{k,I}+\eta_{k,I} \end{aligned} \tag{20a}$$

$$\begin{aligned} r_{k,Q}(t) &= \sum_{i=0}^{L_1-1}\alpha_{k,i}\int_{nT_b}^{(n+1)T_b} r_k(t)c_{k,I}(t-\tau_{k,i})\sin(\theta_{k,i})dt \\ &= D_{k,Q}+S_{k,Q}+A_{k,Q}+\eta_{k,Q} \end{aligned} \tag{20b}$$

where L_1 is the number of fingers of Rake, and $L_1<L$. The variances of $\eta_{k,I}$ and $\eta_{k,Q}$ can be derived similar to [3]~[5]

$$VAR(\eta_{k,Q})=VAR(\eta_{k,I})=\frac{N_0(NT_c)^2U_k}{4L_1} \tag{21}$$

while desired data for the kth mobile user

$$D_{k,I}=\frac{\sqrt{P}}{2}b_kNT_cU_k \text{ and } D_{k,Q}=\frac{\sqrt{P}}{2}d_kNT_cU_k \tag{22}$$

where U_k is a normalizing factor for TD-SCDMA base station to keep the transmitted power constant regardless of the number of paths. It is given by

$$U_k=\sum_{n=0}^{L-1}\alpha_{k,n}^2$$

Similar to Ref. [3]~[5], we can derive the variances of self interference and multi-access interference of Rake receivers as following

$$\begin{aligned} &VAR[S_k|\{\alpha_{k,i};\ \theta_{k,i}\}] \\ &= VAR[S_{k,I}|\{\alpha_{k,i};\ \theta_{k,i}\}]+VAR[S_{k,Q}|\{\alpha_{k,i};\ \theta_{k,i}\}] \\ &= PT_c^2(2N\chi-\mu)/2 \end{aligned}$$

and

$$\begin{aligned} &VAR[A_k|\{\alpha_{k,i};\ \theta_{k,i}\}] \\ &= VAR[A_{k,I}|\{\alpha_{k,i};\ \theta_{k,i}\}]+VAR[A_{k,Q}|\{\alpha_{k,i};\ \theta_{k,i}\}] \\ &= PT_c^2(k-1)2N\chi/2 \end{aligned}$$

where

$$\chi=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}\alpha_{k,j}^2\alpha_{k,m}^2$$

and

$$\mu=\sum_{j=0}^{L-2}\sum_{m=j+1}^{L-1}(m-j)\alpha_{k,j}^2\alpha_{k,m}^2$$

From Eq. (20) and Eq. (21), let $N_{noise}=S_k+A_k+\eta_k$, the variance of the interference plus noise is written by

$$\begin{aligned} VAR[N_{noise}|\{\alpha_{k,i};\ \theta_{k,i}\}] &= VAR[\eta|\{\alpha_{k,i};\ \theta_{k,i}\}] \\ &+ VAR[S_k|\{\alpha_{k,i};\ \theta_{k,i}\}]+VAR[A_k|\{\alpha_{k,i};\ \theta_{k,i}\}] \end{aligned}$$

$$= \frac{N_0(NT_c)^2U_k}{4L_1} + PT_c^2(2N\chi - \mu)/2 + PT_c^2(k-1)N\chi/2 \tag{23}$$

The averaged BER of rake receiver considered the channel estimation error can be obtained using the previous results, we have

$$BER = Q\left(\sqrt{\frac{D_k^2}{2VAR(N_{noise}|\{\alpha_{k,i};\ \theta_{k,i}\})}}\right) \tag{24}$$

where

$$D_k^2 = (D_{k,I}^2 + D_{k,Q}^2)/2.$$

From Eq. (21) to Eq. (24), we also can derive the BER formula of two cases: ideal Rake and no Rake.

$$BER_{ideal} = Q\left(\sqrt{\frac{D_k^2}{2VAR(N_{ideal}|\{\alpha_{k,i};\ \theta_{k,i}\})}}\right) \tag{25}$$

where

$$VAR[N_{ideal}|\{\alpha_{k,i};\ \theta_{k,i}\}]$$

$$= VAR[\eta|\{\alpha_{k,i};\ \theta_{k,i}\}] = \frac{N_0(NT_c)^2U_k}{4L}$$

and

$$BER_{no-rake} = Q\left(\sqrt{\frac{D_k^2}{2LVAR(N_{noise}|\{\alpha_{k,i};\ \theta_{k,i}\})}}\right) \tag{26}$$

Remark: The BER_{ideal} in fact is a lower bound for the Rake under multipath environment, since it ignored the terms of $VAR[S_k|\{\alpha_{k,i};\ \theta_{k,i}\}]$ and $VAR[A_k|\{\alpha_{k,i};\ \theta_{k,i}\}]$, to assume that they can be cancelled by the Rake processing. However, the self interference and the multiaccess interference can not be removed, because the spreading codes are no longer orthogonal in the multipath environment. Thus, the BER_{ideal} is only a theoretic bound. The system simulation in next section will show this point.

The formula (24～26) will determine the BER range of the TD-SCDMA systems under the complex conditions of multiusers and multipaths. An ideal RAKE-receiver with BER (25) needs as many correlators as there are propagation paths in the channel. All practical implementations, however, have much fewer correlators. On a channel that fades very quickly, these few correlators collect the signal from the paths that are strongest on average. In this situation the classical analysis of the ideal RAKE receiver found in the presented papers can be applied to receivers with fewer correlators than propagation paths. Often, however, the fast fading is slow enough for the receiver to collect the signal of the paths with the largest momentary power. This leads to a combination of selection and maximum ratio combining.

V. Performance Evaluation

In the TD-SCDMA case, parameters $\tau_{k,l}$, for $1 \le l \le L$, have been assumed fixed. Conversely, parameters $\alpha_{k,l}$, $\theta_{k,l}$, for $1 \le l \le L$, have been considered as statistically independent and identically distributed random variables. Independent uniform probability distributions on [0, 2] have been assumed for $\theta_{k,l}$, $1 \le l \le L$, while the random variables $\alpha_{k,l}$, $1 \le l \le L$, have been characterized statistically by independent Releigh distributions, which is shown in Fig. 6.

Numerical results determined by means of computer simulations are presented here. Each in-phase, quadrature data bit and each pilot signal bit is spread by a specific sequence from a set of 64 bits Walsh codes operating, all the 4 paths considered in our channel model may be resolved, and all the 48 mobile users in the TD-SCDMA cell in the simulation are active, which means that we had to face the complex problem of multipaths and multiusers. The sliding correlations between the received signal and the local generated version of the pilot signal shown in Fig. 4 are performed over a time interval 112.5 ns long. For each trial, the codes assigned to the users are randomly chosen from the set of Walsh codes of length 64 and the pilot signal is given in Fig. 6.

We have noted that BER as a function of parameter SINR, is influenced by the number of tracked replicas, our solution is to track the first four most powerful replicas. This result is due to the fact that the multipath interference is relatively stronger in the epoch 0.2 T_b, shown in Fig. 6. Hence, in deriving the numerical results shown in Fig. 7, where the finger number L_1=4.

The curves in Fig. 7 depict the performance of RAKE techniques under the situation of 48 users and 4 paths. The results of Fig. 7 are based our theory formulas (24～26), except the SIR Rake which is a system simulation. The SIR Rake has been thought of good BER performance[11],[12], the figure also gave the comparison with the SIR Rake, shown by the second upper curve, which is denoted by " — ◦ " line. Without the Rake processing, the BER performance of the 48 mobile users is very poor, which is shown by the upper curve in Fig. 7, which means that the original orthogonal CDMA channels are no longer being keep, and the MAI caused the BER performance be deteriorated. However, in ideal case, if the Rake receiver can catch all the diversity information, the BER performance of the users can be greatly improved, which is by the lower curve in Fig.

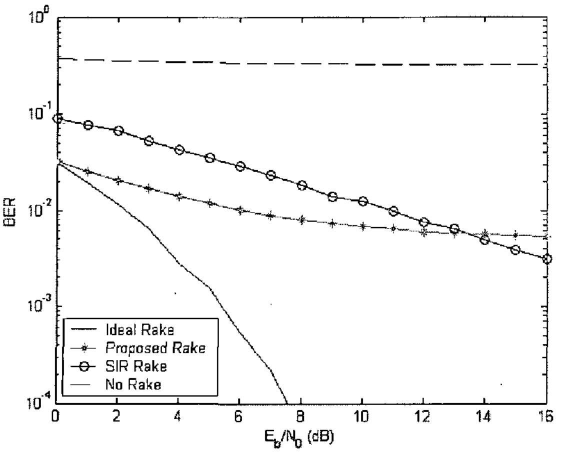

Fig. 7. The bit error rate versus the E_b/N_0 for the rake receivers under the situation of 48 users and 4 fingers.

7, and many presented papers were show the result to readers. Because we need consider the practical application and implementation complexity, we can use the Rake receivers with 4 fingers only to collect the data energy in time diversity, the second curve give us the theoretic BER effect of proposed Rake receivers based on Eq. (24). Though the proposed Rake scheme has not reach the ideal curve based on Eq. (25), it also has improved the BER performance of TD-SCDMA mobile receivers much, and is better that the BER curve of SIR Rake. The SIR Rake has been thought of good BER performance[11],[12].

Fig. 8 gives the system simulation for the proposed Rake receiver, it shows the relation of BER and the fingers of the proposed mobile Rake. We can see that the mobile can not keep normal wok without Rake, the 4 fingers of Rake can improve the BER much, and 6 and 8 fingers of Rake have similar BER performance, since the energy of time diversity focus on the first several fingers. Considering the low complexity and cost, the Rake receiver in this paper tends to the Rake with 4 fingers only.

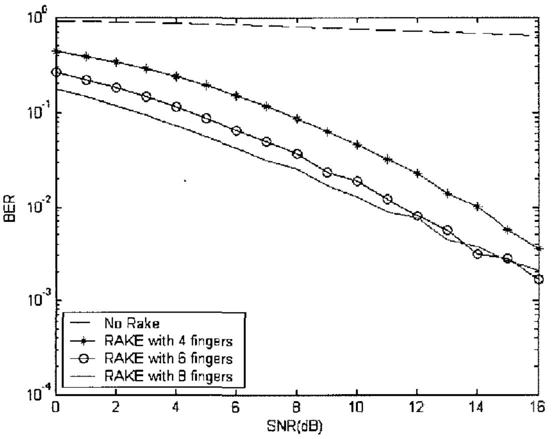

Fig. 8. The bit error rate for the proposed rake receivers under the situation of 48 users and different number of fingers.

Ⅵ. Conclusion

We proposed an efficient Rake implementation method based pilot sequences, which assures a good channel estimation accuracy for TD-SCDMA downlink channel. A sliding correlation of the proposed Rake receiver is performed at each receiving end between the received signal and the locally generated version of the pilot signal to obtain the finger positions This paper has investigated the performance of Rake receiver in the complex case of multipath and multiusers, and pointed that there is a range of BER for Rake receiver. Numerical results have been used to demonstrate the performance of the proposed RAKE receiver in terms of bit error probability under multipath fading propagation and multiusers conditions. A performance comparison with a RAKE receiver having perfect knowledge of all the channel parameters and SIR Rake[11],[12] has also been carried out in order to demonstrate the good behavior of the proposed approach.

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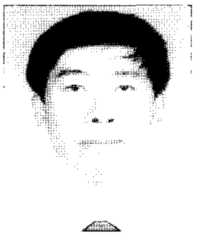

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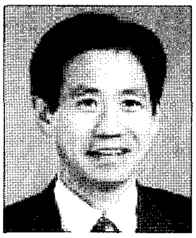

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